CREATION OF FISHERY HABITAT IN ESTUARIES

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Introduction

Most fishery organisms harvested in the United States are dependent on estuaries at some stage in their life cycle. This is especially true for the fisheries along the South Atlantic coast and in the Gulf of Mexico. During 1985, the total US commercial fishery catch was 6.3 billion pounds, with a value to the fisherman of $2.3 billion. Forty-three percent of the commercial harvest came from the Gulf of Mexico and the South Atlantic, with a direct value to the fisherman of over $753 million (Thompson 1986). The largest and most valuable commercial fisheries, menhaden and penaeid shrimp, are concentrated in the Southeast. Furthermore, approximately 55 percent of all US marine recreational fishes are caught in this region. Over 96 percent of this entire regional catch is dependent on the varied habitats within estuaries.

The role of particular estuarine habitats in supporting fishery productivity depends on the fishery species and other factors including developmental stage, time of year, geographic location, and physical and chemical characteristics of estuarine waters. All estuarine habitats are utilized to some extent, and each may be critical to at least some life-stage of a fishery organism. Most of the recent research on habitats has focused on vegetated bottoms such as seagrass meadows and intertidal marshes. These vegetated areas appear to be selected for use by the young of many species, as evidenced by some of the highest densities of juvenile fishery organisms recorded for any habitat. In some cases, it has also been shown that vegetation provides important nursery functions that include increased food for growth and structure for protection from predators. Open-water habitats, however, are also valuable and in many instances may be critical for maintaining productivity of fishery organisms. Passes are known to be utilized as spawning grounds for some fishes and are certainly important as migratory pathways. Relatively deep open-bay waters are utilized as staging areas for juveniles before migration offshore and as feeding grounds for many adults. Shallow open-water areas including tidal flats, delta bottoms, and channels and creeks support large numbers of juveniles, and these habitats are considered to be primary nursery grounds for many fishery organisms including menhaden and spot (Day et al. 1982, Weinstein and Brooks 1983). Small creeks and channels also provide access to intertidal marshes and refuge from stranding during periods of low water. Other estuarine habitats such as highly productive oyster reefs may also be valuable, providing structure and food to fishery organisms such as juvenile crustaceans and fishes.

Establishing the relative value of estuarine habitats for fishery organisms is a primary goal of NMFS habitat research. Direct exploitation of vegetated intertidal habitats has been established (Zimmerman and Minello 1984a), and these habitats would appear to be among the most important in relation to fishery productivity (Turner 1977). Unfortunately, the ratio of vegetated bottom to open water in most estuaries of the United States is decreasing. Marshland is being lost at high rates due to natural phenomena such as rising sea level and land subsidence, compounded by factors related to the exploitation of coastal regions such as man-induced subsidence, reduced sediment input, and increased saltwater intrusion (Baumann et al. 1984). Although not restricted to the Southeast region, rates of vegetation loss appear to be greatest in this area where the Nation's largest marshes occur. In Louisiana, rates of marsh loss have been estimated at 50 square miles per year, corresponding to almost 1 percent of the vegetated wetlands available (Gagliano et al. 1981). Major declines in fisheries, related to habitat loss, have not been identified in this region, but this should not lead to complacency. Detrimental effects of marsh loss may be delayed by the conversion of freshwater marshes into brackish marshes at the same time that brackish and saline marshes are lost to open water. In addition, the marsh degradation process itself may provide fishery organisms with some short-term benefits (Browder et al. 1985). These situations are temporary, and the long-term loss of marsh must eventually have a negative effect. Population growth in the coastal regions of the United States is increasing, and the increase in the Southeast is substantially greater than the national average. With this growth, which is accompanied by industrial and real estate development, we can expect estuarine habitat losses to accelerate.

Considering the magnitude of wetland loss in our nation's estuaries, responsible management of our fishery resources demands action to combat this problem. First and foremost, we must conserve present wetland areas whenever possible. In addition, we may be able to create vegetated estuarine habitats to replace those lost. Dredged material is potentially useful for the creation of intertidal wetlands. The CE is responsible for maintaining navigable waterways, and finding ways of disposing of dredged material without destroying estuarine habitats is a large and continuing problem. Under most circumstances, disposal in upland areas may be the most ecologically sound course of action. However, it may be unreasonable to assume that open-water disposal can always be avoided and is always undesirable. In coastal areas where marsh loss is a persistent problem, uncontaminated dredged material may be useful for creating valuable vegetated habitats. As part of the MOA initiated between NMFS and CE to examine the possibility of using dredged material to create productive fishery habitats, a cooperative research program has been initiated. The goal of this program is to utilize the specific capabilities of these agencies to restore and create coastal habitats in order to maintain and enhance fishery productivity. Before this goal can be attained, a number of basic questions regarding estuarine habitats must be addressed.

a. Is the displaced open-water habitat critical to fishery organisms?

b. Is there an optimal open water to vegetated bottom ratio for estuaries, and does it vary with the type of fishery organism or geographic location?

c. Are wetlands such as marshes themselves critical for fishery species or can their functions be replaced by other habitats?

d. Will man-created marshes function in a similar manner as natural marshes?

Answers to these questions require information on the relative value of estuarine habitats and how habitats function to provide necessary requirements of fishery organisms. Habitat research in the Southeast Fisheries Center of NMFS has been devoted to this problem, and substantial progress is being made toward both of these objectives. Initial projects identified under the MOA for the Southeast Region have been designed to contribute to this research effort through the experimental manipulation of vegetated estuarine habitats.

Current Research on Habitat Functions for Fishery Organisms

The following discussion is based largely on NMFS work with penaeid shrimp conducted in the salt marshes of the Texas coast. Many of the conclusions, however, may be applicable to other fishery species.

Abundance patterns of organisms in estuaries are useful in determining the importance of habitats under the assumption that organisms can and will select habitats that are optimal for growth and survival. Until recently, it has been difficult to determine density patterns of fishery species in shallow marsh habitats because of the inefficiency of traditional sampling techniques in these vegetated areas. The development of a large cylindrical drop-sampler has enabled us to overcome many of these problems (Zimmerman et al. 1984). Comparisons of paired samples show that juveniles of fishery organisms, including brown shrimp, blue crabs, and spotted seatrout, select intertidal *Spartina alterniflora* habitat over adjacent nonvegetated bottom (Zimmerman and Minello 1984a; Figure 1). Other field research currently under way using the drop-sampler indicates that these organisms exhibit similar selection patterns in other estuarine marshes dominated by *Spartina patens*, *Scirpus maritimus*, and *Juncus roemerianus*. Some fishery species such as white shrimp do not show the same attraction to intertidal marsh over open water, and these species would appear to have different habitat requirements.

Measurements of density patterns alone are inadequate for determining whether a habitat provides critical ecological requirements of a particular species. For example, a species may be abundant in a habitat due to physical transport related to current patterns in an estuary, and that habitat per se may not be required to maintain the productivity of the species (Miller et al. 1984). Experimental work on growth and survival in estuarine habitats is necessary to determine how habitats function for an organism. Caging experiments in salt marshes have shown that growth rates of brown shrimp are apparently related to the presence of *Spartina alterniflora* (Figure 2). In this case, increased growth rates within vegetation have been correlated with increased densities of benthic infauna and epifauna in this habitat. In contrast, growth rates of white shrimp, a species which does not appear to specifically select *Spartina*, were similar in vegetated and nonvegetated cages (Zimmerman and Minello 1984b). These data, along with additional information on laboratory growth rates, depletion rates of benthic infauna, and stable

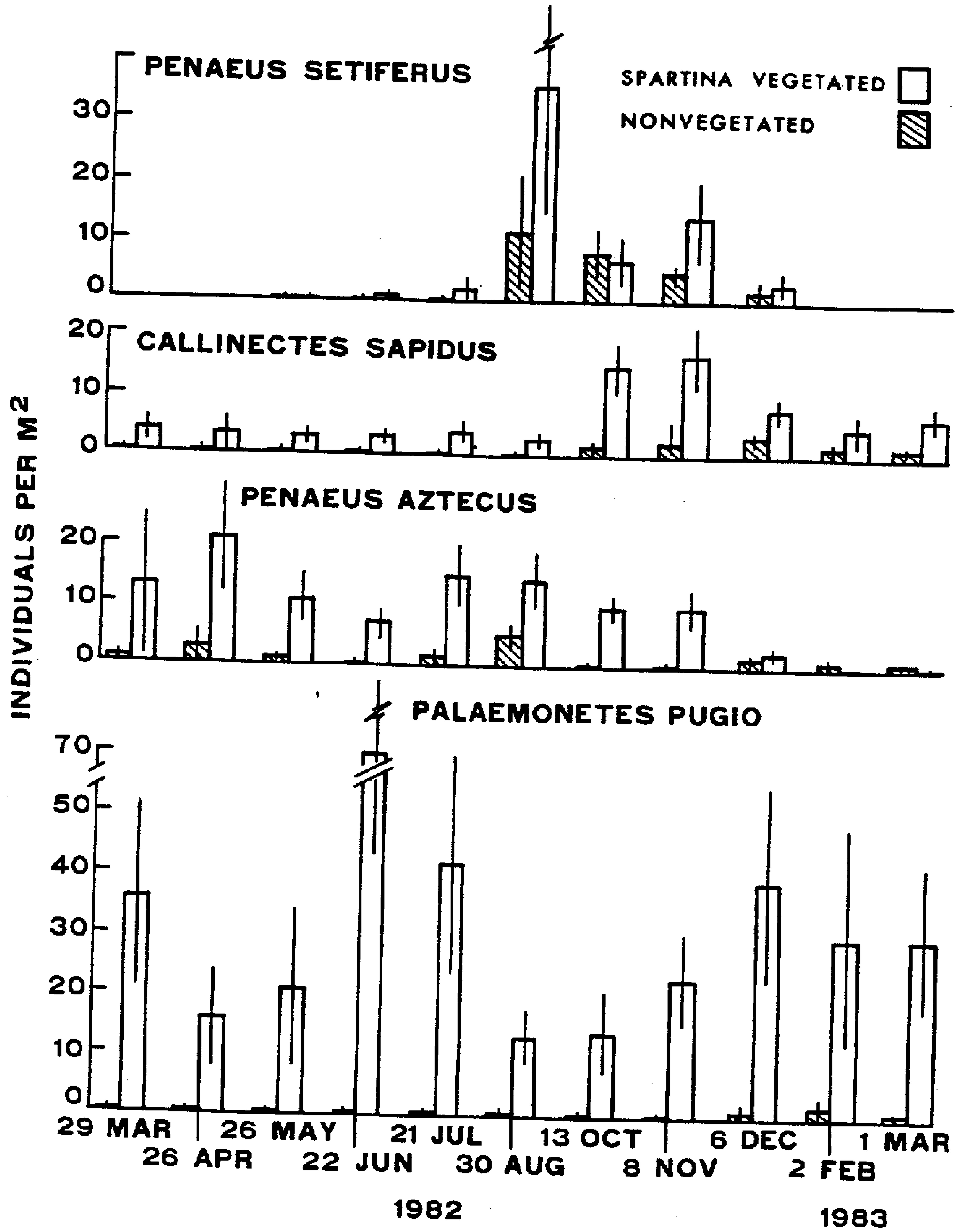

Figure 1. Mean densities of macrocrustaceans in a Galveston Bay salt marsh (taken from Zimmerman and Minello 1984a)

carbon isotope ratios, indicate that, evolutionarily, brown shrimp and white shrimp have partitioned the available resources (Zimmerman, Minello, and Dent; unpublished manuscript).

Plant structure provided by a Spartina alterniflora marsh also appears to provide brown shrimp with protection from some fish predators. The presence of both live and simulated Spartina has been shown to reduce fish predation rates in laboratory experiments (Minello and Zimmerman 1983, Zimmerman

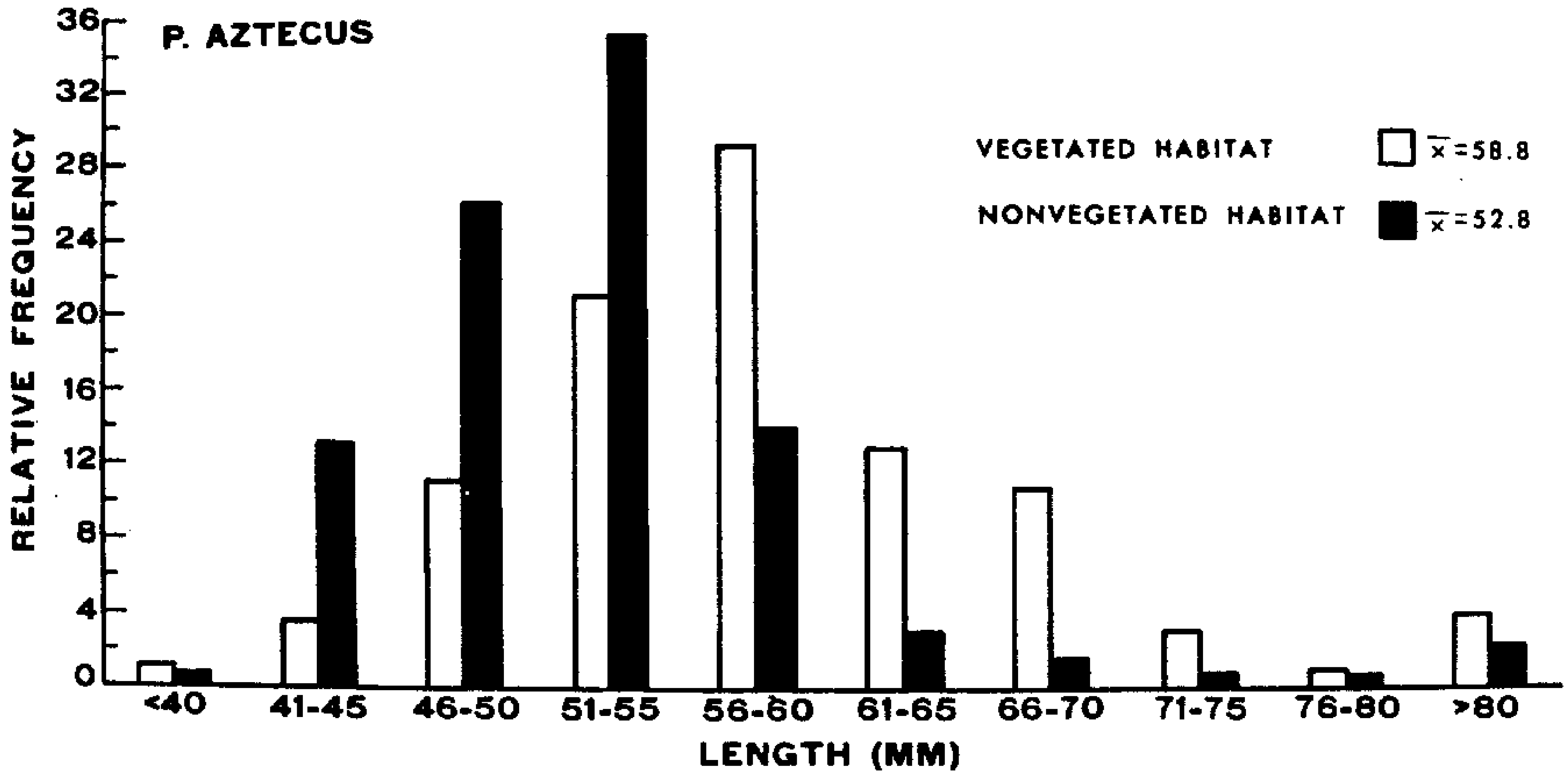

Figure 2. Final size-frequencies and mean sizes of brown shrimp grown in cages for 27 days with and without Spartina alterniflora. Initial size was approximately 30 mm (taken from Zimmerman and Minello 1984b)

and Minello 1984b). A size-frequency analysis on small shrimp collected with our drop-sampler suggests that mortality in estuarine nurseries, presumably due to predation, may be as great as 70 percent over a 2-week period. In such instances, relatively small reductions in predation rates may have large impacts on survival and on recruitment to the fishery. As in the growth studies, there also appears to be a difference between brown shrimp and white shrimp with respect to the protective nature of vegetation. The presence of vegetative structure does not appear to protect white shrimp from predators to the same extent that it protects brown shrimp (Minello and Zimmerman 1985).

The above experimental evidence indicates that brown shrimp directly exploit estuarine marshes and obtain critical ecological requirements from these habitats. The ability of a species to exploit intertidal marshes, however, depends upon additional environmental characteristics. Tidal flooding patterns and marsh geomorphology control access to these vegetated habitats. Tides of relatively low diel and high seasonal amplitude extend access periods during seasons of relatively high water levels. Increased intertidal edge in marshes may also facilitate access for exploiting estuarine species. In the northwestern Gulf of Mexico, tides are dominated by seasonal high- and low-water stands, and estuarine marshes tend to be highly reticulated, having a large amount of edge. In part, this reticulation may be related to the

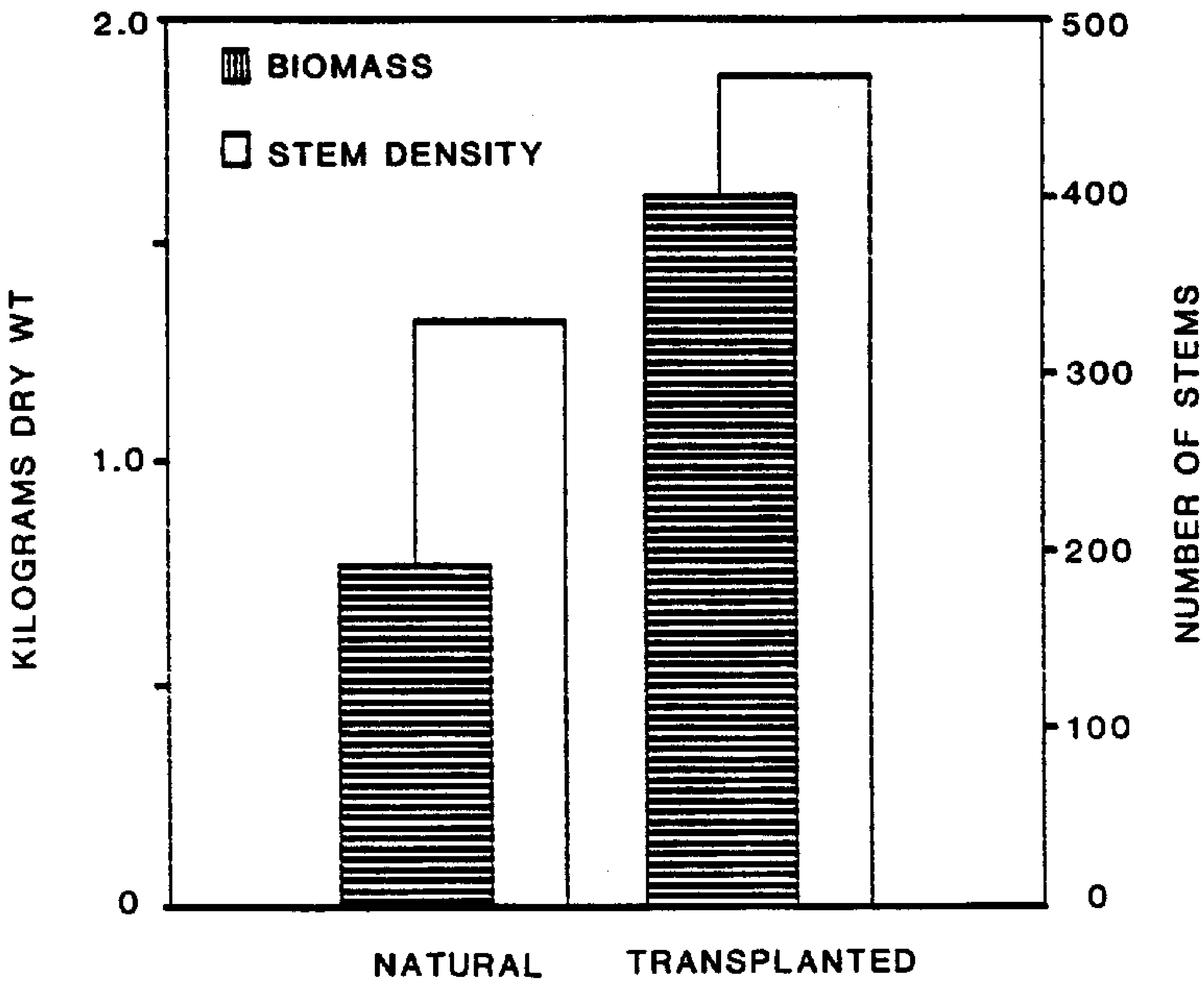

Figure 3. Mean biomass and stem density for 2.8-sq-m samples of *Spartina alterniflora* in natural and transplanted marshes on the Texas coast

MOA Research on Marsh Construction

The presence of vegetation, in itself, does not appear to define a healthy productive marsh for fishery organisms. Utilization may be restricted to only small portions of transplanted marshes unless other factors are considered in marsh construction. Evidence suggests that a large amount of edge is beneficial, and that natural creeks and channels connecting the inner marsh with the open bay provide flushing to maintain moderate soil salinities for healthy plants, provide access to more of the marsh surface for fishery organisms, and facilitate escape of organisms under low-tide conditions. The cooperative research projects in the Southeast Region between the CE and NMFS under the MOA are being developed to examine the importance of habitat edge and accessibility in the creation of vegetated estuarine habitats. The project in Galveston, Texas, involves the creation and experimental manipulation of *Spartina alterniflora* marshes. In North Carolina, the research entails

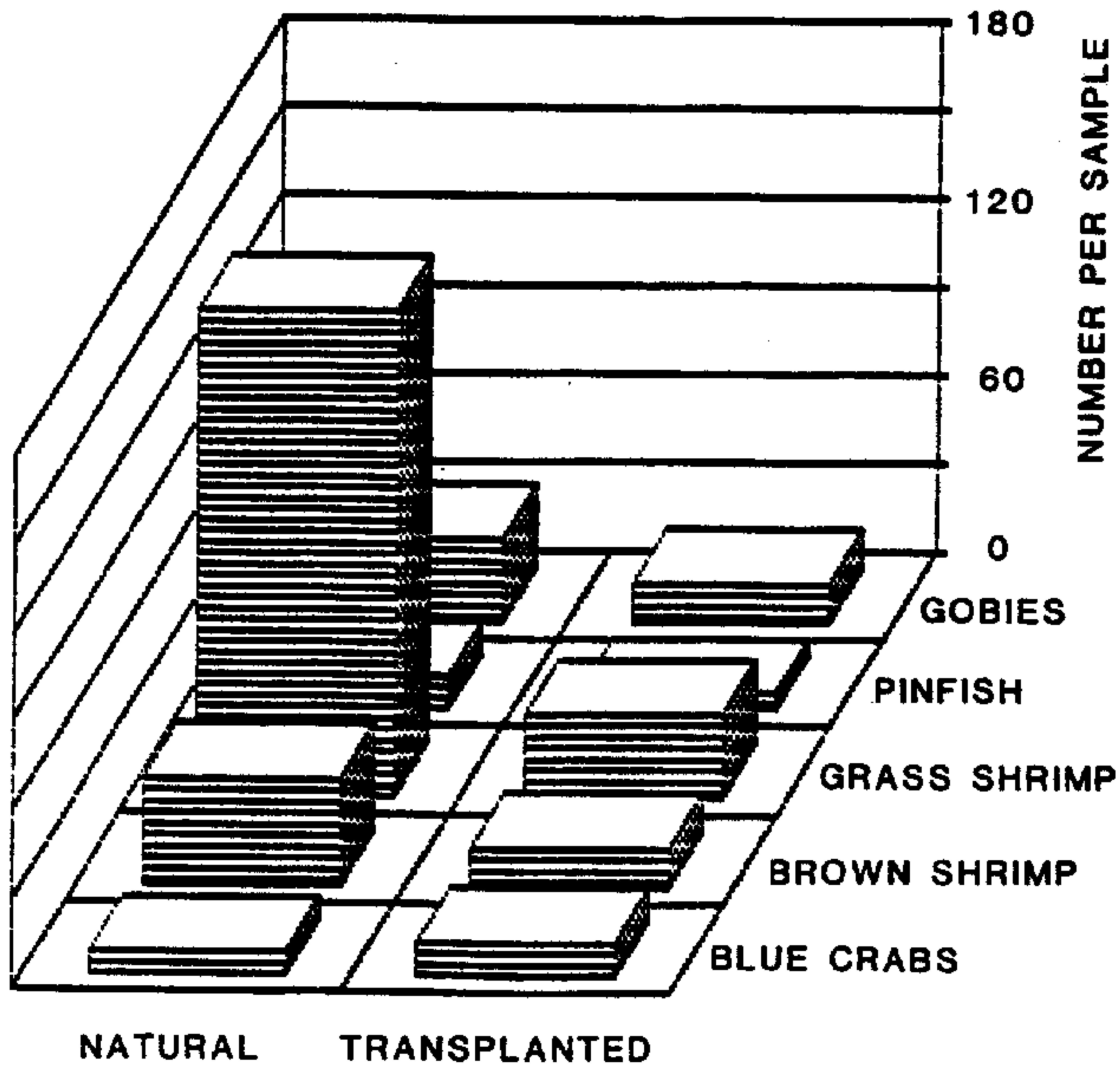

Figure 4. Mean densities (number/2.8 m^2) within natural and transplanted _Spartina alterniflora_ marshes along the Texas coast

grading of existing dredged material and creating both submerged and emergent vegetated habitats.

Research in Galveston Bay, Texas, is being designed to test the hypothesis that the construction of access channels will increase the density of fishery organisms in a _Spartina alterniflora_ salt marsh and allow utilization of a greater portion of the marsh surface under flood tide conditions. The experimental design involves creating U-shaped channels in plots of salt marsh transplanted on dredged material. The densities of fishery organisms in these plots will then be compared with densities in control plots. Two study areas have been identified in the Galveston Bay system. At one, a transplanted _Spartina alterniflora_ marsh has already been established, and the construction of channels in experimental plots is necessary. In the other study area, a small-scale experimental placement of dredged material is planned within a designated disposal area. At this site, an intertidal salt marsh approximately 400 m long and 50 m wide will be created along the shoreline of an existing dredged material bank. The basic design at both sites involves dividing a 400-m length of vegetated shoreline into four blocks, each block having a 100-m frontage on the bay and extending 50 m upland. The blocks will be subdivided into two sectors (each with 50-m frontage), and these will be randomly designated as either control or experimental sectors. Within experimental sectors, two channels (approximately 2 m wide and 0.5 m deep) will be constructed to allow water exchange and provide animals with access to the inner marsh. Each channel will extend a minimum of 25 m inland from the shoreline, and the channels will be connected in the inner marsh to improve circulation.

Sampling to determine densities of fishery organisms will be conducted in the spring and late summer. These periods coincide with abundance peaks of brown shrimp, white shrimp, and many recreational fishes in Galveston marshes. The drop-sampling technique will be used to collect organisms at flood tide within the vegetation at the outer edge and in the inner portions of the marsh. Cores taken within each drop sample will be used to determine the abundance of potential food organisms, including benthic infauna and epifauna. Vegetation will be clipped at the substrate surface, and the biomass of Spartina alterniflora will be compared between experimental and control sectors. In addition, soil salinities will be monitored, and sampling sites will be marked and revisited at approximately 1- to 2-month intervals to check for differences in revegetation.

A second MOA experimental project is being conducted in coastal North Carolina in the vicinity of the Beaufort NMFS Laboratory. This project is similar in that the importance of accessibility to salt marshes by fishery organisms will be tested. The completely different tidal regime in this area and the abundance of submerged vegetation in the system provide an opportunity to expand the experimental design. Various combinations of experimental plots containing seagrass habitat, reticulated and nonreticulated marsh vegetation, and nonvegetated bottom will be created and tested for their utility for fishery organisms.

Conclusions

The importance of estuaries for US commercial and recreational fisheries, combined with accelerating habitat loss in these estuaries, requires action on the part of managing agencies in order to avert major declines in fishery stocks. Conservation measures have not and, in some instances, cannot control habitat loss. The MOA between the NMFS and the CE has been initiated in an effort to restore and create estuarine habitats in order to maintain and enhance fishery productivity. In order to create fishery habitat, however, we need to know what habitats are valuable, what habitats are critical, and what habitats are replaceable. None of these questions can be answered without additional research on how estuarine habitats function for fishery organisms. Initial projects of the MOA address some of these questions through the experimental manipulation of vegetated estuarine habitats created with dredged material. In the process, information on critical characteristics of these habitats for fishery organisms will also be acquired.

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